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Characterization of a tree wake using three short-range WindScanners

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Motivation

A project called Single Tree was initiated in the Wind Energy Department of the Technical University of Denmark (DTU), with the objective to characterize the flow around a solitary tree.

The presence of solitary trees in a flat terrain introduce heterogeneities, which modify the characteristics of the wind. The wind-trees interaction is a topic of study in applied research areas, like wind energy, where the estimation of wind resources and associated turbulence levels is necessary to describe accurately the wind conditions over an area. In the case of rough landscapes typical uncertainties in the estimation of the terrain roughness can result to 10% uncertainty in the annual energy production estimate [1].

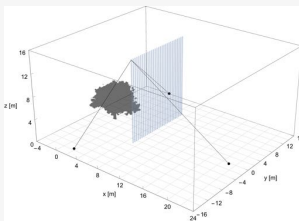
Method

For the needs of this study a European Oak tree (*Quercus robur*), located on the shore of the Roskilde fjord in Denmark, was selected. Such a tree is commonly found in forests or solitarily in urban and rural environments in temperate regions. Using a commercial terrestrial laser scanner, the dimensions and the detailed geometry of the tree were measured and two meteorological masts equipped with multiple in-situ sonic anemometers were used to provide reference measurements of the wind conditions. The wind flow characterization was performed using three short-range WindScanners [2][4].



Photo of the tree under study and of the measurement equipment that it was used in the experimental campaign

Scanning pattern



Drawing of the scanning pattern which was used to measure the dimensions of the tree wake

The three short-range WindScanners were placed on the ground and programmed to scan synchronously a 2D vertical plane, with an area of 16 m x 16 m. The scanning plane was located 8 m from the tree in the downwind direction and it consisted of vertical lines, which were separated by a distance of 0.5 m.

Remote sensing instrument (Short-range WindScanner)

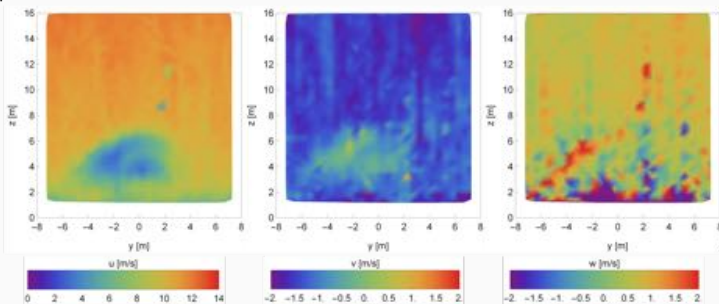


Photo of one of the short-range WindScanner.

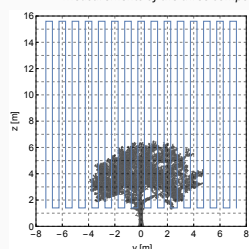
A short-range WindScanner consists of a Doppler wind lidar and an optical scanner head. The lidar is a continuous-wave, monostatic, infrared Doppler lidar, capable to measure both the amplitude and sign of the projection of the wind vector to its line-of-sight [3]. The transmitted light is steered in the atmosphere using a scanner head that deflects the lidar's line-of-sight using two independently rotating wedge-shaped prisms, each with a deflection angle of 30°. Through the implementation of the aforementioned configuration the short-range WindScanner can scan a volume defined within a cone with an aperture angle of 120°.

3D wake measurements of a tree

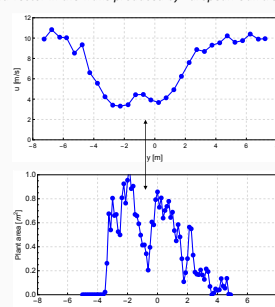
An example of a 10-min mean wake of the tree is presented, based on the radial wind speed measurements acquired from one of the short-range WindScanners. The wake has been measured during a period when the wind was flowing from a direction that approximately aligned to the normal axis of the scanning plane (y-axis). A maximum deficit of 63% between the upwind and downwind speed is observed.



Measurements of the three components of the wind vector in the wake produced by European Oak tree.

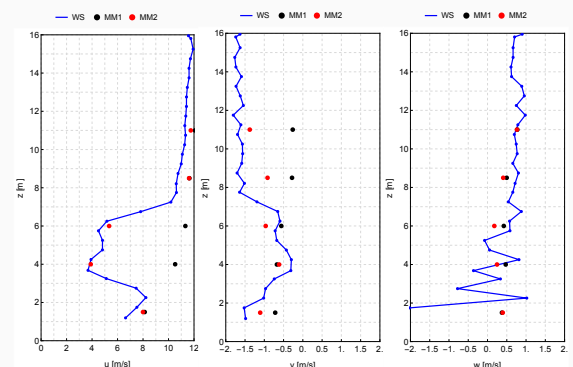


The tree geometry (black) resolved using a terrestrial laser scanner and of the trajectory (blue) which was followed to scan an area in the downwind side of the tree



The 10-min mean u-component of the wind in the wake of the wake produced by European Oak tree measured at 4 m height above ground (top) and average plant area of a horizontal cross section at the same height (bottom).

Vertical wind profile in the wake of a tree



The 10-min mean vertical profile of the three components of the wind vector in the wake produced by European Oak tree measured by the short-range WindScanner (blue) and sonic anemometers (red) and the corresponding upwind condition measured by sonic anemometers (black)

Conclusions

The acquired data reveal the details of a tree wake dimensions, quantify the corresponding wind deficit and provide an insight on the characteristics of the flow around the tree. These observations contribute to the understanding of the wind-trees interaction and furthermore shall be used for the validation of fluid dynamics numerical models.

References

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